CFD ASSESSMENT ON DIFFERENT BED HEIGHT EFFECT OVER DRAG MODEL OF FLUIDIZED BED

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A report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Mechanical Engineering

Faculty of Mechanical Engineering
Universiti Teknologi Malaysia

JUNE 2013

Bismillahirahmanirahim

To my beloved wife and kids, with their sincere prayers afforded me

to accomplish this work, and my supportive lecturer,

Assoc. Prof Dr Kahar bin Osman

ACKNOWLEDGEMENT

In the name of Allah SWT, the Entirely Merciful, the Especially Merciful. All praise is due to Allah SWT for divine blessings, The Lord of the worlds who create the entire universe. It is You we worship and You we ask for help. We prayed to Allah SWT to lift the rank of Prophet Muhammad SAW and guide us to the straight path.

The completion of my master would not have been possible without an invaluable support, wise guidance and constant advises from my supervisor, Assoc. Prof Dr Kahar bin Osman who really believed in my potential and provided me the opportunities during my research. I would like to express my sincere gratitude to him and May Allah SWT Bless him and his family.

Special thanks goes to my beloved wife, Mashitah binti Mezelan for her constants supports, both my lovely children Rayyan Ar Zhafran and Rania El Zhafirah, the gems that I've been blessed with for their sacrifices. All these supports come together which makes me stronger to encounter all the burden throughout my research. Not forgetting, my respective colleagues Norikhwan, Mohd Azali, Norelyani, Suzilawati and Kamariah Isa, who enriched my learning by sharing their wealth of knowledge to motivate me accomplish this research.

After all the struggles along the way, finally the research is regarded as completed and ready to be submitted although I really believe it is far from being great. During the whole Masters course, I'm feel really grateful to Allah SWT as it is a significant learning process that matures me tremendously and gave me some confident level which I could adapt it to my career as a Mechanical Engineer. This work also yields from the efforts of all the lecturers who taught me during my study in UTM, May Allah SWT blessed you all. Thank you.

ABSTRACT

Fluidized beds are widely used by various industries because of low pressure drop, uniform temperature distribution, high heat transfer rate and large contact area which enhances chemical reaction. It seems that the efficiency of the fluidized bed depends on the knowledge of the flow behaviour which are important for scaling, design and optimization. In modelling of gas-solid phase, drag force is one of the main mechanisms for inter-phase momentum transfer. Therefore in this study, 2D model of fluidized bed was developed to study the effect of using various drag models over different bed height of H/D ratio such as 0.5, 1 and 2. The drag correlations of Gidaspow, Wen Yu, Syamlal-O'Brien, Hill Koch Ladd (HKL) and Representative Unit Cell (RUC) are to be implemented using a multiphase Eulerian Granular Model (EGM) to simulate the interaction between phases. Simulation of the model is be conducted via commercial CFD software ANSYS FLUENT 14. The main contribution of this study is to identify the important of bed height during gasification process in order to contribute in the development of TNB Research of IGCC. From the results obtained show that EGM greatly suitable for dense particle flow. As overall, the result shows Wen Yu and Gidaspow drag model are suitable for dense fluidized bed application. While for Syamlal-O'Brien drag model is more suitable for all range of application. Finally for RUC and HKL can predict highest drag at volume fraction which is more likely occur in dense phase.

ABSTRAK

Fluidized bed seringkali digunakan secara meluas oleh pelbagai industri kerana ia mampu memberikan tekanan yang rendah, pengagihan suhu yang seragam, kadar pemindahan haba yang tinggi dan kawasan sentuhan besar yang mana dapat meningkatkan tindak balas kimia. Oleh yang demikian kecekapan *Fluidized bed* bergantung kepada pengetahuan mengenai sifat bendalir yang mana ia sangat penting dalam menentukan skala reaktor, rekabentuk dan pengoptimum sesuatu reaktor. Dalam model fasa gas-pepejal, daya seretan merupakan salah satu mekanisme utama bagi pemindahan momentum setiap fasa yang berlaku. Oleh yang demikian dalam kajian ini, model 2D *Fluidized bed* telah dibangunkan untuk mengkaji kesan penggunaan pelbagai model seretan dengan perbezaan ketinggian *bed* mengikut nisbah H/D sebagai contoh 0.5, 1 dan 2. Model seretan *Gidaspow, Wen Yu, Syamlal-O'Brien, Hill Koch Ladd* (HKL) dan *Representative Unit Cell* (RUC) akan diguna pakai dengan menggunakan *Multiphase Eulerian Granular Model (EGM)* bagi melaksanakan simulasi bagi mendapatkan kesan interaksi bagi setiap fasa. Simulasi model akan dilaksanakan dengan menggunakan perisian CFD komersial ANSYS FLUENT 14. Sumbangan utama kajian ini adalah untuk mengenal pasti kepentingan ketinggian *bed* semasa proses pengegasan dalam memberi sumbangan terhadap pembangunan penyelidikan TNB mengenai IGCC. Daripada keputusan yang diperolehi menunjukkan model seretan bagi Wen Yu dan Gidaspow sesuai digunakan untuk aplikasi padat *fluidized bed*. Manakala bagi model seretan Syamlal-O'Brien boleh digunakan untuk semua aplikasi. Akhir sekali untuk model seretan RUC dan HKL mampu meramal ketinggian maksimum untuk seretan yang berlaku pada jumlah kecil dimana ia lebih cenderung berlaku pada fasa padat.

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LIST OF SYMBOLS

A	-	Constant in RUC drag model
A	-	Constant in Syamlal-O'Brien drag model
$A*$	-	Constant in Syamlal et al frictional viscosity model [Pa]
A_p	-	Projected area [m^2]
A_r	-	Archimedes number
B	-	Constant in RUC drag model
B	-	Constant in Syamlal-O'Brien drag model
C_D	-	Drag factor on single particle
C'_D	-	Drag factor on multiparticle system
c_i	-	A distance in the HKL drag model
d_s	-	Diameter of phase *s*
e_{ss}	-	restitution coefficient for phase *s*
f	-	Kinetic energy loss factor in the Burke-Plummer equation
F	-	Drag factor in HKL drag model
F_{dr}	-	The general drag force [$kg.m/s^2$]
f_i	-	particle distribution function
F_r	-	Friction factor from Johnson et al frictional viscosity
F_0, F_1, F_2, F_3	-	Drag constants in the HKL drag function
g	-	The gravitational acceleration (9.81 m/s^2)
g_0	-	The general radial distribution function
$g_{0,ss}$	-	The radial distribution function for phase *s*
$k_{\theta,s}$	-	Conductivity of granular temperature [kg/ms]
K_{sg}	-	Drag factor of phase s in phase [kg/m^3s]
K_{sp}	-	Drag factor of a single particle [kg/m^3s]

ΔP	-	Pressure drop [Pa]
P_s	-	Solids pressure [Pa]
Q	-	Volumetric flow rate [m^3/s]
$\nabla . q_s$	-	Diffusive flux of fluctuating energy [$kg/m.s^3$]
Re	-	The Reynolds number
U	-	Velocity [m/s]
t	-	Time [s]
Δt	-	Interval [s]
ω	-	Factor in the HKL drag correlation
$\propto_g$	-	Gas phase volume fraction
$\propto_s$	-	Solid phase volume fraction
θ_s	-	Granular temperature [m^2/s^2]
μ	-	Viscosity [kg/m.s]
μ_g	-	Gas viscosity [kg/m.s]
μ_s	-	Granular viscosity [kg/m.s]
ρ_g	-	Gas density [kg/m^3]
ρ_s	-	Granular density [kg/m^3]
$\emptyset$	-	Angle of internal friction [^{0}]
$\emptyset$	-	Shape factor used in the Ergun equation
π	-	The irrational number π
δ	-	Kronecker delta

LIST OF ABBREVIATIONS

2D	-	Two dimensional
3D	-	Three dimensional
CFD	-	Computational Fluid Dynamic
EGM	-	Eulerian granular modelling
Eqn.	-	Equation
FDM	-	Finite Difference Method
FEM	-	Finite Element Method
FVM	-	Finite Volume Method
H/D	-	Height bed over diameter
HKL	-	Hill Koch Ladd
IGCC	-	Integrated Gasification Combine Cycle
RUC	-	Representative Unit Cell
TNBR	-	Tenaga Nasional Berhad Research
UDF	-	User Define Function
U_{mf}	-	Minimum Fluidization Velocity

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Fluidized beds are widely used by the chemical, mineral, pharmaceutical, and energy industries because of low pressure drop, uniform temperature distribution, high heat transfer rate and large contact area which enhances chemical reaction. In the chemical industry, fluidized bed reactor is central component of combustion, pyrolysis, and gasification. Local gas holdup circulate in the whole fluidized bed are incredibly important hydrodynamic parameters to determine a uniform mass and energy distribution and also gasification efficiency. Time average data is more meaningful than temporary in the design of commercial-scale fluidized bed. It can be said that the efficiency of the fluidized bed depends on the knowledge of the flow behaviour which are important for scaling, design and optimization.

Based on Joachim Lundberg et al (2008), drag and gravity are the mainly dominating conditions in the momentum equation of the granular phase. The use of different drag models significantly affect the flow of granular phase by influence the predicted bed expansion and particle concentration inside the dense phase bed. Thus it depends on better control of the fluidization process which highly demands a better understanding of fluidized bed hydrodynamics.

Eulerian granular modelling (EGM) approaches based on the two fluid model have been thought as the most suitable choice when simulating the hydrodynamics of fluidized beds. In these approaches, gas-solid interactions are modelled via the inter-phase of drag model. On other word, selection of a drag model plays significant role for any multiphase flow approach. Due to its high significance, this occurrence was frequently investigated by other researcher . The main goal of these study was to get an optimum drag model for better fluidized bed hydrodynamics. Therefore drag force is one of the dominant mechanisms for inter-phase momentum transfer.

1.2 Research Objective

The main objective of this study was focused on modelling and simulating fluidized bed of TNBR IGCC using commercial CFD code ANSYS FLUENT which can determine the influence of using different drag model on the behaviour of fluidized bed. In addition it also will determine the effect of interaction between particles and momentum transfer between phases in the aspect of pressure. Therefore this paper will be studied using different bed height which corresponded to H/D such as 0.5, 1, and 2. Simulation will be conducted in 2D geometry due to the lack of computer resources such as memory and processor speeds.

1.3 Problem Statement

As we know, IGCC is an alternative industrial application which can reduce carbon emission under pre-combustion approach. However there are few issues and problem still arises in IGCC. Therefore failure to access in obtaining scaling, design and optimization of fluidized bed reactor was due to the lack of knowledge about the flow behaviour of fluidization.

It seems the problem occur in TNBR gasifier pilots was unable to determine the occurrence of the transition regime of fluidized bed. As the objective meaning of the changing parameter is not known until the further research was needed. Thus with the application of drag models its considerably impacted the flow of the granular phase.

1.4 Research Hypothesis

Due to the linear nature of the complex bed hydrodynamics, it is also possible that the model accounting for the frictional force between the particles cannot reproduce the effective viscosity of the dense phase in the areas involved particles transport, such as bubble wake. Fractional flow of air through the fluidized bed actually intercept in the region of dense phase, up just near the surface of the wall, a small void is large since the packing of particles close to the wall is not as effective as in most of the bed. Indirectly, it will reduce the flow through the crossing dense phase bulk and reduce the drag forces between gas and solid phases and also will reduce the velocity of the particle.

1.5 Scope of Research

The scope of this research is focused on simulating the bed height over different drag model on 2D geometry. The drag model which are going to be implement are Syamlal-O'Brien, Gidaspow, Wen Yu, Hill Koch Ladd (HKL) and Representative Unit Cell (RUC). Simulation of the model will be conducted via commercial CFD software such as ANSYS FLUENT 14. Further simulation will be conducted to determine the prediction of drag force in fluidized bed over bed expansion and also will focus on user defined function (UDF) of HKL and RUC as additional drag model which is not include in software.

1.6 Significant of the Study

The significance of this study is to identify the important of bed height during gasification process. Furthermore the success of this study will contribute in the development of an IGCC gasifier with high efficiency of energy production, low in production cost and safe to use environmentally.

1.7 Theoretical Framework

The following is the theoretical framework related to the study of drag model using different bed height for the gasifier.

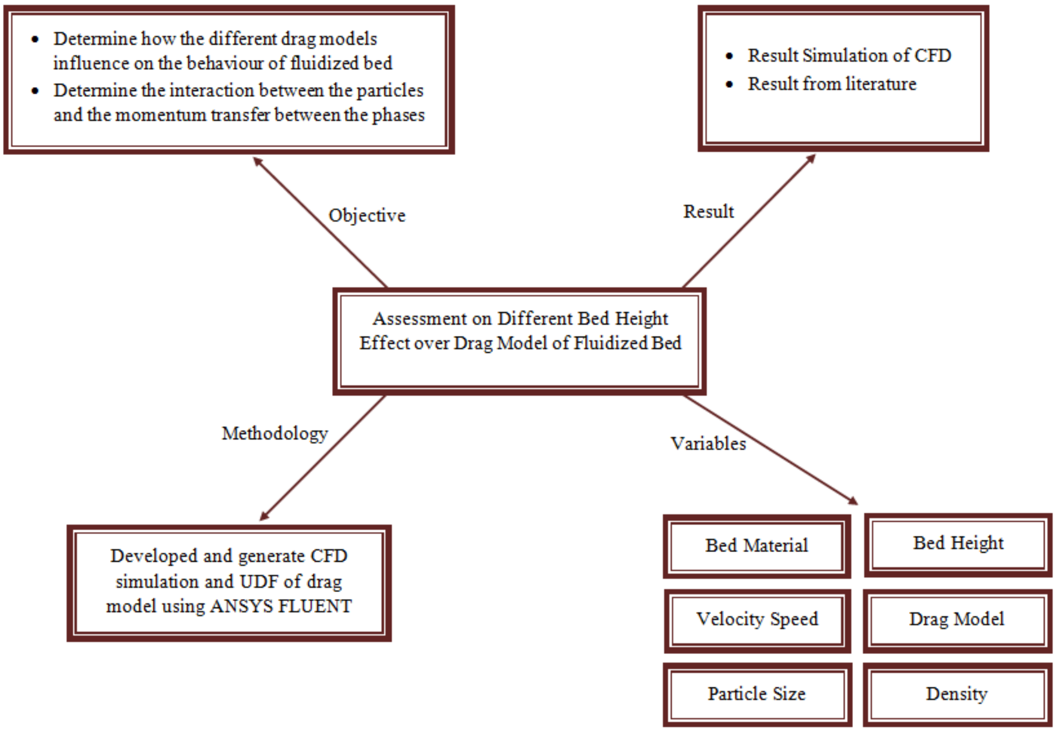

Figure 1.1: Mind mapping of theoretical of framework

1.8 Dissertation Organization

This study consists of 6 chapters starting with Chapter 1 which explains the background of the study. In Chapter 2 we described the theory used in this study, and the research done so far in connection with this study. Studying the hydrodynamic behaviour of a fluidized bed is a necessary step for the analysis the process. Detailed methodology and analysis is presented in Chapter 3 including flowchart, identification of research variable, equation used by ANSYS FLUENT, collection and analysis of data, and also the accuracy and correctness of this study is being checked. However in Chapter 4 we used modelling to simulate drag model and illustrate the results of the simulation in term of the effect of different bed height. In this chapter also we discussed on the result obtained. Conclusion are summarized in Chapter5. We also give some recommendation for future improvement in order to optimize the gasifier of fluidized bed.

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